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Patentanmeldung Nr. Patent application No. Demande de brevet n°

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Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

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Bezeichnung der Erfindung/Title of the invention/Titre de l'invention:
(Falls die Bezeichnung der Erfindung nicht angegeben ist, siehe Beschreibung.
If no title is shown please refer to the description.
Si aucun titre n'est indiqué se referer à la description.)

Phase locked loop demodulator with gain control

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Field of the invention

The invention concerns the field of demodulation of modulated signals and amplification of obtained demodulated signals. More particularly the invention relates to architecture of a circuit or a set of circuits realizing those functions. In its different applications, the invention notably relates to the reception of modulated signals like, for example, radio signals, telecommunication signals, telephone signals, audio base-band signals, wireless analog signals, video signals etc... The invention then also concerns any reception system for such signals. Such reception systems or devices can be a phone in wireless standard, DECT for example, a radio receptor, a wireless controller..: Low cost wireless communications can also take profit from the invention. The invention proposes also a method for demodulating a modulated signal and amplifying the obtained demodulated signal.

Background of the Invention

Figure 1 presents a standard architecture of the demodulation of a modulated signal followed by an amplification of the obtained demodulated signal.

Such a standard architecture is for example implemented and described in the data sheet of UAA3515 from Philips semiconductor. In such architecture the demodulation is realized by a demodulator DEM using a classical phase locked loop including a phase detector PDT, a loop filter LFI and a voltage controlled oscillator function VCO. Then the demodulated signal FDM is provided to a first amplification stage G1 comprising a high gain amplifier G_∞ and passive elements C1, R1 and R2. In the integrated circuit technology, the use of passive elements generally implies the use of at least two pins of connection P1 and P2 as shown on figure 1. Then the output of the amplifier stage G1 is classically connected using an intermediate filter INF to a second amplification stage G2 including a complex gain control amplifier GGC. This second amplifier stage is then connected to a processor PRO that process the signal in order that this last can be exploited.

Such architecture presents the drawbacks to need two connection pins, to need external components that take place on PCB and moreover impose their time constant (this time constant is even greater that the R1C1 multiplication has to be high in order not to deform the audio signal), to need the presence of a complex gain control amplifier that often deteriorate noise floor characteristics.

Summary of the Invention

It is an object of the present invention to propose a new architecture realizing the demodulation of modulated signals and the amplification of the obtained demodulated signal that does not present the drawbacks of the above-presented architecture and that enables an enhanced quality for the finally exploited signals.

To this end, the invention proposes a demodulator to demodulate frequency-modulated signals including a Phase locked loop including at least a phase detector, a loop filter and a

Voltage controlled oscillator function VCO, characterized in that said Voltage controlled oscillator function VCO has a modifiable gain.

Said modifiable gain being implemented in the Voltage controlled oscillator function VCO enables the amplification of the frequency variations of the Frequency-modulated signals. Consequently the demodulated Frequency-Modulated signals are amplified when output from the Phase locked loop. The modifiable gain can be implemented in various ways within the Voltage Controlled Oscillator function.

According to an advantageous embodiment, the modifiable gain of said Voltage controlled oscillator function VCO is modifiable using a programmable trans-conductance. In this advantageous embodiment the Voltage controlled oscillator function VCO is controlled by the current output from a programmable trans-conductance. Said programmable trans-conductance enables the transformation of a voltage in current, said transformation generating a current as low as amplification is wished. The less important is said output current of said programmable trans-conductance; the most important is the amplification versus the frequency variations. Said advantageous embodiment is particularly adapted to standard Intermediate Frequencies IF used in wireless communication: 450kHz, 10.7MHz.

According to a preferred embodiment of the invention, the programmable trans-conductance includes a fixed trans-conductance and a current multiplier, the output of said programmable trans-conductance being the output of a summation unit that sums a combination of at least one output of said multiplier.

In advantageous implementation, said second current is taken at an intermediate output of said current multiplier using digitally programmable switches and preferentially MOS switches implement said switches. The command of said MOS switches may then be provided by a digital command on a given number of bits for example, said bits corresponding to the activation of said MOS switches.

The invention also relates to an electronic device able to receive frequency-modulated signals characterized in that demodulation of said signals is realized by a demodulator as described above. A method for demodulating frequency modulated signals according to the invention is also proposed and includes including the steps of providing said frequency modulated signals at the input of a Phase locked loop including at least a phase detector, a loop filter and a Voltage controlled oscillator function VCO, increasing frequency variations by increasing gain of the Voltage controlled oscillator function VCO having a modifiable gain, providing demodulated signals at the output of said the Phase locked loop.

Brief Description of the Drawings

The invention is described hereafter in detail in reference to the diagrammatic figures wherein:

Fig.1 presents the standard architecture of a demodulator followed by amplification of demodulated signals according to the state of the art;

Fig.2 presents the new architecture of a demodulator with integrated gain control according to the invention;

Fig.3 presents an advantageous embodiment of means to modify the gain of the voltage controlled oscillator function according to the invention using a programmable trans-conductance;

Fig.4 presents a preferred implementation of the programmable trans-conductance;

Fig.5 illustrates a reception device according to the invention;

Fig.6 is a block diagram of a method to demodulate a signal according to the invention, said block diagram also describing schematically the invention according to the abstract.

Description of embodiments

Fig. 1 presents the standard architecture of a demodulator DEM followed by amplification of demodulated signals according to the state of the art in a specific second amplification stage G2 including a complex gain control amplifier GGC. This figure has been described above.

In an application, the demodulator receives frequency-modulated signal:

$FM = A \cdot \cos [2\pi f_c t + (f_{dev}/f_{mod}) \sin(2\pi f_{mod} t)]$.

f_{dev} is the deviation of the frequency, f_{mod} is the modulation frequency, f_c the central frequency of the Voltage Controlled Oscillator function VCO. Said central frequency f_c can be the own oscillation frequency of an oscillator included in the function VCO or the divided by M own oscillation frequency of an oscillator included in the function VCO, said own oscillation frequency being equal to a several times M of the central frequency fc, and said oscillator being followed by a divider by M. In this case, the function VCO is considered to include the divider. Any structure known for a Voltage controlled oscillator function VCO allowing having a frequency centered on the modulation frequency of the received signals can be implemented in the state of the art and in the invention. The invention includes supplementary features independently of such means to center the frequency of the voltage controlled oscillator function on the modulation frequency.

The audio processor PRO input signal is then:

$(f_{dev}/K_{VCO}) \cdot G1 \cdot G2 \cdot \sin(2\pi f_{mod} t)$.

K_{VCO} is the gain of the VCO, this gain is fixed in the state of the art. G1 and G2 represent here the value gain of the two amplification stages G1 and G2. The gain G2 is modifiable in order to adapt the amplification of the signal input in the audio processor PRO. The amplitude of the modification of the gain is advantageously centered on a mean value that corresponds to the most commonly required level of amplification by an exploitation system implemented at the output of the audio processor PRO. Such an exploitation system can be, for example, an earpiece with loudspeaker. The modification of the gain of amplification stage G2 then enables to increase and decrease the gain around this mean value.

Such architecture presents some drawbacks. This architecture classically needs external passive elements R1, R2, C1 and two output pins in order to realize connections with those external passive elements. This architecture is limited in term of settle time by the R1, C1 time constant. It has a major impact on the standby mode of a telephone for example. This architecture also needs a complex gain control amplifier GGC in the second amplification stage G1. The DC offset of such a complex amplifier GGC limits the audio processor noise floor performances. As the gain control is implemented after an output pin, the signal level on this output pin is lower than in the invention. It makes the architecture less robust regarding to the ground audio bounce on PCB. The invention enables to avoid all these drawbacks by providing a high quality demodulation and amplification of the demodulated signals with a very simple new architecture.

The main function achieved by the invention is the demodulation of Frequency modulated signals with gain control of the output signals directly done in the Phase locked loop within the Voltage controlled oscillator function VCO.

Fig.2 presents the new architecture of a demodulator DEM' with integrated gain control according to the invention. The Phase locked loop includes a Voltage controlled oscillator function VCO' with a modifiable gain. This modifiable gain enables to increase or decrease the gain of the Voltage controlled oscillator function VCO' in order to adapt the level of the input of an audio processor PRO directly in the Phase locked loop. Such a modifiable gain Voltage controlled oscillator function VCO' can be implemented in various ways.

An advantageous embodiment is then proposed in Figure 3. This embodiment is particularly adapted to standard Intermediate Frequencies IF modulated signals (450kHz, 10.7MHz for example). The Voltage controlled oscillator function VCO' includes a Relaxation Oscillator RO. Relaxation Oscillators are known from one skilled in the art. It is constituted by a capacity, which is charged and discharged by a current. This charge and discharge represent the period of the oscillator. As seen hereinabove, said relaxation oscillator RO can, independently to the invention, be followed by a divider of current in order to center the frequency of the voltage controlled oscillator function VCO' on the modulation frequency of the received signals. The functioning of the Relaxation Oscillator RO is controlled by the sum of two currents: I that classically enables the frequency of the VCO' to be centered on the modulation frequency and IGM coming from the phase locked loop and representing the variations of frequency due to the frequency modulation. According to the invention, the current IGM passes through a programmable trans-conductance GM1. According programmation data PG, the trans-conductance GM1 has the ability to provide a depending on the programmation data PG, more or less important current IGM for a given voltage difference between the output of said loop filter and a reference voltage VREF. Then the gain of the Voltage controlled oscillator function VCO' is proportional to the value of the

programmable trans-conductance GM1. A particular and preferred implementation of the programmable trans-conductance GM1 will be presented in the following.

Fig.4 presents a preferred implementation of the programmable trans-conductance GM1. Said programmable trans-conductance GM1 includes a fixed trans-conductance GM2 classically known in the state of the art. The output of this fixed trans-conductance is a current IGM2. As explained above in the description of Figure 1, the amplification needed is generally dedicated to adapt the level of the input signal of the audio processor in order to obtain exploitable signals at the output of this audio processor. According to the architecture of the invention presented on figure 2, the audio processor input signal is equal to:

(f_{dev}/K_{VCO}). G . sin $(2\pi f_{mod}t)$.

K_{VCO} is here modifiable. Its value has to be centered on a value that enables a mean value that corresponds to the most commonly required level of amplification by an exploitation system implemented at the output of the audio processor PRO. The amplitude of variation of K_{VCO} can also be determined. For example, it is then considered in the following that the current IGM2 is a maximum value for IGM that correspond to a maximum of K_{VCO} and consequently to a minimum of the audio processor input signal. Then, said programmable trans-conductance GM1 advantageously includes also a binary weighted current multiplier MUL presenting, in this particular example, a ratio $1/2^N$ with N = 1 to n at each of its outputs. Such a definition means here that a current equal to IGM2/ 2^n is provided on output n of the multiplier MUL, n being included in interval [1:N]. In this embodiment, classical current multiplication means like current mirror can be used in the invention. According to the preferred embodiment of the invention, switches S[n] are connected to the multiplier outputs. Said switches are then linked to a summation unit SUM. The switches are controlled by programmation data PG made of n bits. It has to be noted that, on figure 4, a single output n and a single switch are represented for clearness reason. A summation unit SUM is connected to said switches. The summation unit SUM output current IGM is equal to IGM2 x $\sum_{n/PG} (1/2^n)$. For example, for programmation data PG on 3 bits code 101, the output current IGM is: IGM2 x (1 x ½ + 0 x ¼ + 1 x 1/8) = 0.625 IGM2. Said outputs can also be permanently connected to the summation unit SUM.

The summation unit SUM can sum as many currents as there are permanently connected outputs or outputs connected using a switch. Every combination of the outputs of the multiplier MUL are possible according to the invention. Every kind of outputs of a multiplier can also be used according to the invention. Multiplier MUL outputs can be any kind of multiple of the multiplier input current IGM2. Amplitude of modification of IGM is then defined by an interval of current, defined by limits that can be taken by the sum. Said interval is advantageously centered on the above-invocated mean value.

It can also occur that IGM2 is a minimum value that corresponds to the higher possible required gain. In this case, the multiplier, for example, provides IGM2 and the summation is an integer multiple of IGM2. A multiplier according to the invention can also provide any multiple of IGM2 at its outputs, said multiples being then summed according to the invention. In this case, for example, $IGM = IGM2 \times \sum_{n/PG} 2^{n-1}$. For example, for a 3 bits code 101, the output current is:

$IGM2 \times (1 \times 4 + 0 \times 2 + 1 \times 1) = 7 \times IGM2$.

According to the invention, the Voltage controlled oscillator function VCO' includes a multiplier. The modification of the gain of the Voltage controlled oscillator function VCO' is then realized using commutation of currents. The decreasing of the gain results in an amplification of the frequency variations in the Relaxation Oscillator VCO for a given signal. Consequently the formed demodulated signal FDM is amplified in a customizable way regarding what would have been obtained with a fixed trans-conductance GM2. The change of the gain of the Voltage controlled oscillator function VCO' generates a change in the output gain. It has to be noted that the gain of the amplifier of the first amplification stage in the architecture of the state of the art has to be high (classically around 20) while the gain of G needs generally to be around 1 or 2.

The invention enables to reduce the time necessary to establish a balance in reception chain of a reception device comparing to the state of the art. Effectively, the invention enables not to be limited by the time constant of external elements. The invention enables not to have external elements. The invention enables to reduce the silicon size required to realize functions of gain control amplification more than 100 times (no complex gain control amplifier). The invention enables not to need a complex gain control amplifier. The DC offset of this last amplifier induces limitations in the noise floor performance of the audio processor. According to the invention, the DC offset of the amplification is removed before the audio processor by the AC coupling realized by the filter INF on figure 2. As the gain control is implemented before the output pin of, the signal level on this pin is higher than in the state of the art architecture. It makes the architecture more robust regarding to the ground audio bounce on PCB.

Consequently, the new architecture according to the invention provides an amplification equivalent to the one realized in the state of the art without having the drawbacks of this last. To summarize, the invention enables improvements concerning silicium occupation, audio quality, pinning count, external component and PCB area. System consumption is also reduced as the settling time of the receptor is reduced (no more time constant). Effectively, the standby time being reduced, the consumption is reduced.

Fig.5 illustrates a reception device according to the invention. This figure is a very schematic representation of such a reception device. It includes at least an antenna ANT enable at least to receive frequency-modulated signals FM (Radio-Frequency RF or other), a demodulator DEM' according to the invention, a reception chain RX with a processing unit PROC. Said reception

chain RX and demodulator DEM' are advantageously connected to an audio system AUD enable the exploitation of demodulated signals FDM. This can be an earpiece with a loudspeaker LSP. Advantageously the reception device also includes also a transmission chain TX advantageously linked to the processing unit PROC and to the audio system AUD. This is the case for telephone for example. Then the audio system includes also a microphone MIC for example.

Fig.6 is a block diagram of a method to demodulate a signal according to the invention, said block diagram also describing schematically the invention according to the abstract. A method for demodulating frequency modulated signals according to the invention includes the step INP of providing frequency modulated signals FM to an input of a Phase locked loop PLL including at least a phase detector, a loop filter and a Voltage controlled oscillator function VCO', the step of amplifying frequency variations by modifying/decreasing gain of the Voltage controlled oscillator function VCO', said Voltage controlled oscillator function VCO' having a modifiable gain, the step OUP of providing demodulated signals FDM at an output of the Phase locked loop.

The architecture strictly as disclosed on Figure 2 and the embodiments presented in figure 3 and 4 are not exclusive. Other alternative architectures and embodiments may be derived in accordance with principles of the invention defined in the Claims to accomplish the same objectives.

Claims:

1. A demodulator to demodulate frequency modulated signals including a Phase locked loop including at least a phase detector, a loop filter and a Voltage controlled oscillator function VCO, characterized in that said Voltage controlled oscillator function VCO has a modifiable gain.

2. A demodulator as claimed in Claim 1, wherein the gain of said Voltage controlled oscillator function VCO is modifiable using a programmable trans-conductance.

3. A demodulator as claimed in Claim 2, wherein the programmable trans-conductance includes a fixed transconductance, a current multiplier, the output of said programmable trans-conductance being the output of a summation unit that sums a combination of at least one output of said multiplier.

4. A demodulator as claimed in Claim 3, wherein said second current is taken at an intermediate output of said current multiplier using digitally programmable switches.

5. A demodulator as claimed in Claim 4, wherein MOS switches implement said switches.

6. An electronic device able to receive frequency modulated signals characterized in that demodulation of said signals is realized by a demodulator as claimed in one of the Claims 1 to 5.

7. A method for demodulating frequency modulated signals including the steps of :
   - providing said frequency modulated signals at the input of a Phase locked loop including at least a phase detector, a loop filter and a Voltage controlled oscillator function VCO,
   - increasing frequency variations by increasing gain of the Voltage controlled oscillator function VCO having a modifiable gain,
   - providing demodulated signals at the output of said the Phase locked loop.

"Phase locked loop demodulator with gain control."

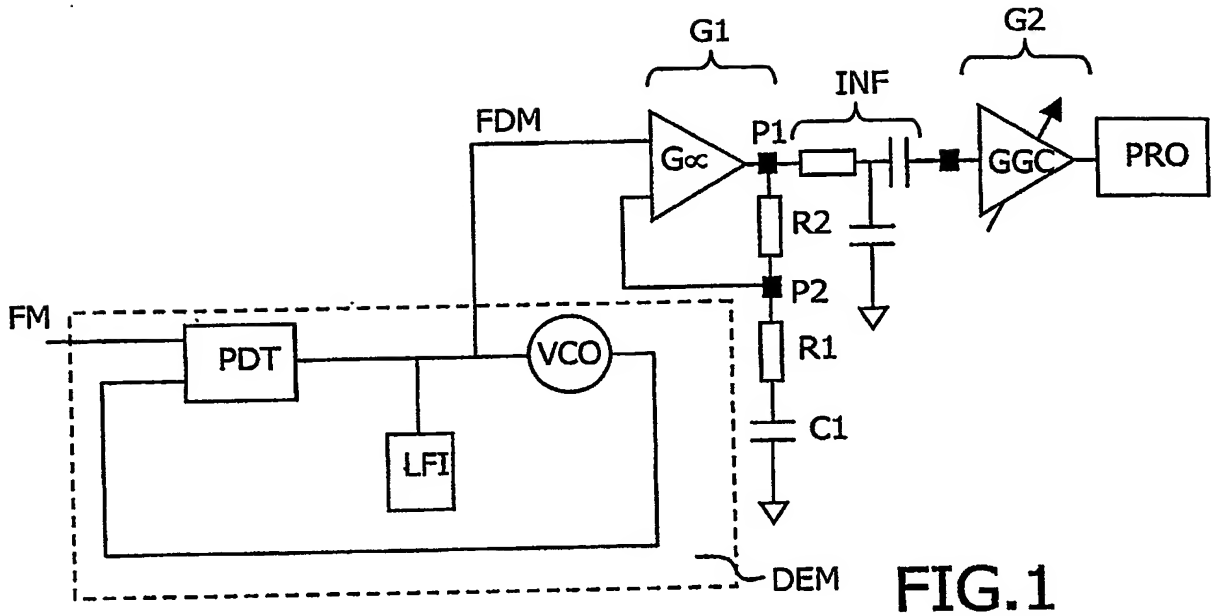
Abstract:

The invention relates to a demodulator to demodulate frequency modulated signals FM including a Phase locked loop PLL including at least a phase detector, a loop filter and a Voltage controlled oscillator function VCO', characterized in that said Voltage controlled oscillator function VCO' has a modifiable gain.

The invention enables to eliminate drawbacks presented by the classical implementation of a complex gain modifiable amplifier at the input of demodulated signals processing means.

Application: demodulation of modulated signals: wireless phone, home network...

FIG.6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G2
INF
FDM
P1
Gα
GGC
PRO
R2
P2
FM
PDT
VCO
R1
LFI
C1
DEM

FIG.1

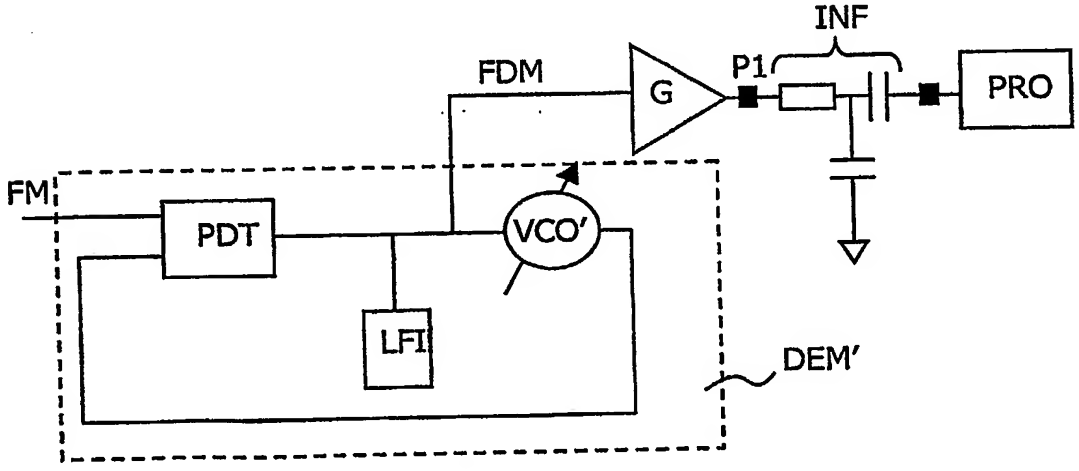
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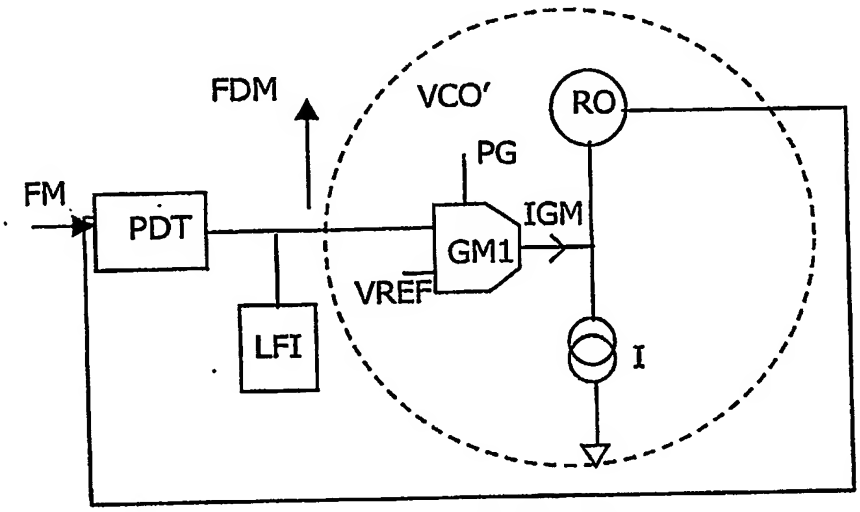
FIG.2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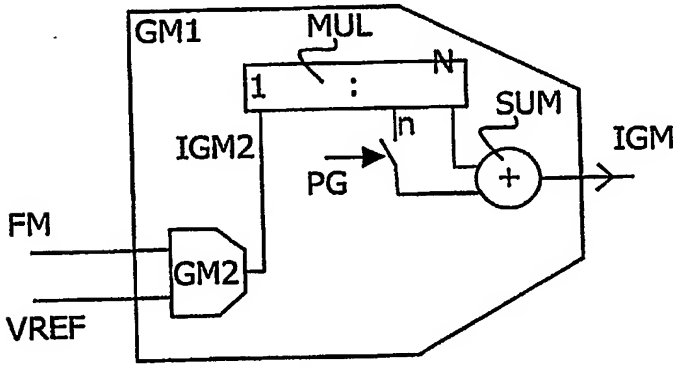
PG
FM
PDT
IGM
GM1
VREF
LFI
I

FIG.3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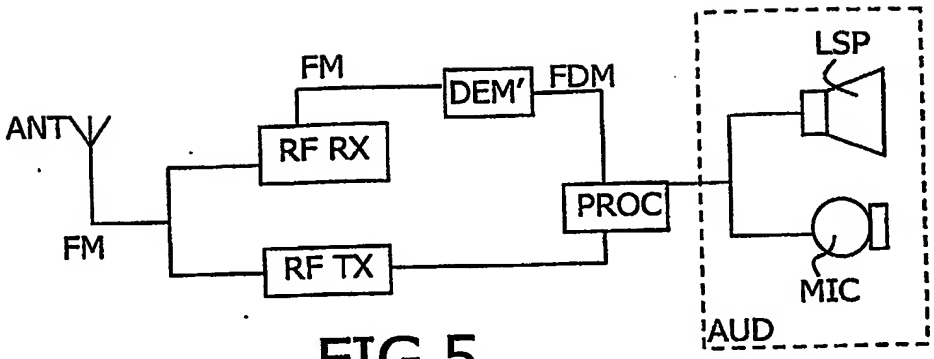
VREF

FIG.4


ANT
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RF TX
FM
DEM'
FDM
PROC
LSP
MIC
AUD

FIG.5

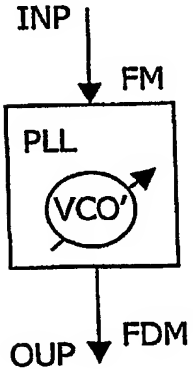
INP
FM
PLL
VCO'
OUP
FDM

FIG.6